FIRE REHABILITATION IN TINTIC VALLEY, UTAH
USING NATIVE AND EXOTIC SPECIES

by

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ABSTRACT

FIRE REHABILITATION IN TINTIC VALLEY, UTAH
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The 1999 railroad fire in Tintic Valley, Utah was followed by the initiation of a large scale seed mix comparison study. This study compared current exotic seed mixes used by the Bureau of Land Management (BLM), 2 native seed mixes, and a mix of both native and exotic species provided by the U.S. Department of Agriculture, Agricultural Research Service (ARS). Seeds were drilled in a Wyoming big sagebrush [*Artemisia tridentata ssp. Wyomingensis* Beetle & A. Young] community and were aerial broadcast followed by 1-way chaining in a pinyon-juniper [*Pinus edulis* Engelm. and *Juniperus osteosperma* (Torr.) Little] community, with 5 randomized blocks treated in each community. Aerial cover, sum of nested frequency, and density were recorded for all herbaceous species as well as shrub age class and density for 2 years following seeding in fall of 1999. Mixed model analysis was used to determine significance of treatment effects.

For the drill seeding, the Native High diversity, BLM, and ARS mixes had statistically similar and successful establishment and persistence. Both the Native High and BLM mixes had significantly higher ($p < 0.10$) seeded species cover and density than the Native Low mix 2 years after seeding. The Native Low diversity mix had limited seeded species establishment as indicated by the lowest seeded species cover and density in both years. The Native High diversity mix had significantly higher perennial cover and density than the control in the second year. The BLM mix had significantly higher perennial density than the control in the second year. All seed mix treatments as well as the unseeded control were dominated by annual species in both years. Sandy soil texture and the lack of depth regulator bands on the drill seeder may have resulted in seeds drilled too deeply. This would explain lower than expected cover and density values for all mixes.

For the aerial seeding/chaining site, seeded species success was statistically similar among all seed mixes. Unlike the drill seeding, the aerial seeding/chaining was dominated by perennial cover in all treatments except the control. All seed mixes except the Native High diversity mix had significantly lower ($p < 0.10$) total annual species density than the control. Our results show the ability of native seed mixes to establish similarly to exotic seed mixes in a semi-arid environment when seeded at high rates. This study also substantiates the need for revegetation in some form following fire in order to avoid dominance by weeds or invasive annuals. Vegetation measurements in future years will better indicate ability of the seeded species to persist and retard weed invasion in these communities.

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INTRODUCTION

The 1999 fire season in the Great Basin was the worst fire season in at least 35 years. Nearly 931,000 ha burned in the Great Basin in 1999, the majority of which (687,000 ha) burned in Nevada (NIFC 2000). Fires in Tintic Valley, Juab County, Utah were relatively small compared to the total burned acreage of 1999. The Railroad Fire in Tintic Valley was ignited in July by railroad track grinders passing through the valley. Sparks from the grinders ignited fires in 2 separate locations, these later combined into 1 large fire resulting in nearly 25,000 ha burned [Bureau of Land Management (BLM), personal communication]. The pre-burn vegetation included mostly pinyon-juniper [*Pinus edulis* Engelm. and *Juniperus osteosperma* (Torr.) Little] woodlands at the upper elevations and Wyoming big sagebrush [*Artemisia tridentata var. Wyomingensis* (Beetle & A. Young) Welsh]-perennial grass communities at the lower elevations. Plant names follow Welsh et al. 1993.

The majority of the burned area in Tintic Valley is managed by the BLM. The primary responsibility of post-fire rehabilitation belonged to the BLM's Fillmore Field Office and funding comes from the Emergency Fire Rehabilitation program. This program provides funds to implement practices which protect life, property, soil, water (including water dependent resources) and/or vegetation resources; prevent unacceptable on-site and off-site damage to the watershed (erosion control); reduce invasion and establishment of undesirable or invasive species of vegetation; facilitate meeting Land Use Plan objectives; and reduce the invasion and establishment of undesirable and invasive species of vegetation (Bureau of Land Management 1999, MacDonald 1999).

These objectives may exclude the use of any species, whether native or exotic, in the restoration process if they are unable to establish quickly following seeding and provide needed protection from erosion and invasion of weeds. Exotic grasses are often chosen for these rehabilitation projects based on their proven ability to establish quickly, exclude many invasive species, and protect soil resources. In addition, the high cost of seeds of native species compared to those of exotic species for large burned areas has limited their use (Roundy et al. 1997)

Not all wildfires require rehabilitation, often burned areas have the ability to naturally recover if there is residual vegetation, sufficient seeds in the seedbank, or adequate native seed sources nearby. This is more likely on burns at higher elevations where seed sources remain and annual precipitation is higher. Natural revegetation tends to be slow and stochastic on arid and semiarid rangelands, where the amount and timing of precipitation frequently limits or prevents plant establishment and growth (Call and Roundy 1991). Additionally, the invasion of exotic annuals and noxious weeds often reduces the recruitment of early seral native species by physically and temporally out-competing them for soil and water resources. Species such as cheatgrass germinate earlier in the season than many native species and consume moisture many native species require for germination and survival (Harris 1967). This intense competition to new emerging seedlings prevents most native plants from becoming established (Monsen 1994).

Noxious weeds, like squarrose knapweed [*Centaurea virgata* Lam.], are carried into recently burned areas by vehicles, livestock, irrigation water, crop seed contaminants or as entire plants moved by wind or vehicles (Roche and Roche 1989). Knapweed is capable of invading an area quickly and completely following fire, after which it out-competes and actively excludes other species. Following invasion and domination of these or other species, such as cheatgrass, fire frequency and intensity increase as a result of a more continuous fuelbed (Whisenant 1990). This increase in fire frequency results in the perpetuation of the weeds as the system is locked into a negative feedback loop advantageous to the invading exotics. In contrast, perennial grasses hold their green foliage further into the fire season lessening the chances of ignition and often lowering the overall burned acreage.

Areas left un-treated following wildfire are also more susceptible to soil loss through both wind and water erosion. By leaving the soil unprotected with plant cover or litter, high winds and high intensity rainfall are more likely to result in major soil movement. Soil loss may eventually cause an area to cross an abiotic threshold where little or no vegetation can establish or survive without extensive site modifications (Whisenant 1999). These and other factors demonstrate the need to rehabilitate many arid and semi-arid areas following wildfire.

Recent changes in public attitudes and natural resource education has seen the emphasis on production-based revegetation shift to a focus more on multiple use goals, as well as maintenance of diversity and native ecological integrity (Richards et al. 1998). Many natural resource managers are shifting from seeding introduced species with their widespread adaptability to seeding native species in order to maintain or restore the genetic and ecological integrity of native ecosystems (McArthur and Young 1999, Richards et al. 1998). With this shift, federal land managers are having to address the scale-associated problems of reestablishing native plants as part of the management of large landscapes (Richards et al. 1998).

Exotic species such as crested wheatgrass [*Agropyron cristatum* (L.) Gaertner], intermediate wheatgrass [*Elymus hispidus* (Opiz) Meld], and smooth brome [*Bromus inermis* Leysser] were often historically chosen over natives due to their wide adaptability, but also because their seeds are easily grown, harvested, cleaned and sown (Roundy 1999). As a result, exotic species were seeded to thousands of acres of degraded rangeland, often exclusively. These revegetation projects were considered successful when measured against common goals of the time such as soil conservation and forage for livestock (Roundy et al. 1997). Because of the their proven record, availability, and low cost, exotic species are still frequently chosen for use in seed mixtures for fire rehabilitation.

In the early years of range rehabilitation, native species were excluded from use on large-scale revegetation projects due to lack of seed availability and high cost. One example of early native species use comes from the Utah Division of Wildlife Resources program which used native species to rehabilitate big game habitat in Utah (Roundy et al 1997). The Great Basin Research Center in Ephraim, Utah has seeded nearly 400,000 acres since 1958 using many native species locally collected and warehoused by the project (Walker 2002). Native species may be more difficult to establish if they are not seeded properly. Most exotic species were agronomically selected and therefore respond well to agronomic seeding requirements (Stevens 1999b).

Often the lack of data supporting the use of native species on large scale projects limits their use on federal lands. Small scale studies with single species plots often show the failure of native species in arid and semi-arid rangelands when compared to exotic species. Asay et al. (2001) showed in their small scale study using single species plots that under favorable moisture conditions and reduced grazing pressure, native wheatgrasses can successfully establish and persist compared to their introduced couterparts. However, this same study showed the limitations of native species in establishing and persisting in areas where water limitations are severe. This study and others like it attempt to extrapolate large scale conclusions from small scale research. This study explores seed mix success on a large scale in attempt to better obtain these results for landscape level rehabilitation.

The purpose of this study is to compare native and exotic seed mixes for use in fire rehabilitation at an operational scale. The main objective was to compare these mixes when applied using the same operational scale and methods typically used in large-scale fire rehabilitation. We compared 4 seed mixes; (1) a primarily exotic seed mix currently used by the BLM's Fillmore Office, (2) a native high diversity mix, (3) a native low diversity mix, and (4) a mix combining both native and exotic species incorporating several investigational plant materials provided by the Agricultural Research Service (ARS). This study tests the differences between seed mixes as well as differences between each mix and the control (no treatment) with regard to the following: aerial cover, density, and nested frequency of vegetation with special attention given to seeded and invasive species; litter and bare ground cover; the amount of soil lost through a combination of both water and wind erosion; and plant persistence following initial treatment and over time.

METHODS

Study Sites

Two study areas and plant community types were selected within the 1999 Railroad burn in Tintic Valley, Juab County, Utah as representative of lands which are either typically drill-seeded or aerial-seeded followed by 1-way chaining (Fig. 1). The Jericho drill study area supported a Wyoming big sagebrush-grass community prior to burning. This area receives 305-356 mm (30 year average) of precipitation per year (USDA-NRCS 1999). Lower elevation sagebrush-dominated sites are typically seeded by rangeland drill due to the gentle slopes and low tree density. High temperature burns left the area with little or no residual vegetation or ground cover. All drill sites were cleared of remaining trees to allow the rangeland drills to pass unimpeded. Five, 4.9 ha blocks (228 m wide by 213 m long) were located in the Jericho study area between 39E 42'-45'N, 112E 11'-17'W at an elevation between 1650 m and 1680 m.

The Mud Springs study area was selected to represent burned pinyon and juniper woodlands. This area receives 356-406 mm (30 year average) of precipitation per year (USDA-NRCS 1999). These areas are characterized by higher tree density than lower elevation sagebrush communities and include many steep slopes, both of which may preclude the use of the rangeland drill. Because of available equipment, higher success, and lower costs, seeding with the rangeland drill is often preferred by the BLM in all suitable areas, including higher elevation sites with lower tree density. Areas where the rangeland drill is unable to operate are aerially seeded and subsequently chained in 1 direction using 2 crawler tractors and an "Ely" style chain (Cain 1971). The aerial seeding/chaining method of seed application was used at the Mud Springs study area. These areas also suffered high temperature burns which generally left little or no remaining vegetation, except for a few small scattered patches of unburned trees and other vegetation. Variable terrain, burn patterns, and the large area required for the treatments made the task of locating suitable study plots much more difficult than on the Jericho study area. Five, 7.8 ha blocks (365 m wide by 213 m long) were located in the Mud Springs study area between 39E 51'-54'N, 112E 11'-15'W at an elevation between 1769 m and 1799 m.

Seed Mixes

Blocks on both study areas were divided into 5 equal strips, each of which was randomly assigned 1 of 4 seed mixes or to be left as an unseeded control. The BLM aerial and drill mixes (Table 1) were primarily composed of exotic grasses and are used as the standard fire rehabilitation mixes by the Fillmore BLM office. These mixes were used successfully for fire rehabilitation in Tintic Valley after the summer fires of 1996 as well as following other fires in this area (Ott 2001, Ott et al.2003). The BLM mixes were applied at bulk rates recommended by the Fillmore field office. The Fillmore BLM office's method of seeding begins with the contracting and purchasing of market seed at standardized high percentages of Pure Live Seed (PLS) then seeding based on bulk rates. The ARS aerial and drill mixes (Table 2) were added to the study by the Forage and Range Research Laboratory in Logan, Utah.

The ARS mixes contained both native and exotic species and incorporated several improved plant materials and varieties under investigation by the agency. The ARS mixes were seeded at bulk rates recommended by the Logan ARS. The Native High Diversity aerial and drill mixes (Table 3) were recommended by scientists at the USFS Shrub Sciences Laboratory who initiated the study. They comprised up to 8 grasses and 3 shrubs, seeded at rates considered high enough for success. The Native Low Diversity aerial and drill mixes (Table 4) were formulated to apply at rates comparable to those recommended for the BLM and ARS mixes. This was accomplished by deleting several species from both the aerial and drill mixes, thus lowering the number of species seeded and the total bulk rate.

All seed mixes with the exception of the BLM mixes were mixed using large grain mixers at the Utah Division of Wildlife Resources Great Basin Research Center facilities in Ephriam, Utah. BLM mixes were mixed separately by private contractors as part of the Fillmore field office's fire rehabilitation efforts. The rangeland drills used for this project were outfitted with 3 separate seed boxes which could be individually adjusted to seed at different rates. This allowed the mixes to be separated into 3 different sub-mixes allowing differing seeding rates and methods. The Native Low, Native High, and ARS drill mixes were all separated into sub-mixes for use in different boxes on the rangeland drill. The BLM drill mix was combined into 1 mix. This is commonly done to accommodate their older single box rangeland drills still in use. The ARS drill mix was all combined with the exception of the forage kochia [*Kochia prostrata* (L.) Schrader] seed which was seeded in a separate box from the grass seed. Both native drill mixes utilized all 3 seed boxes on the rangeland drill. The mix used in the main box of the drills consisted only of grasses. For the second mix, antelope bitterbrush [*Purshia tridentata* (Pursh) DC] and fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.] were combined for use in a separate box on each drill. The Wyoming big sagebrush seed was kept separate for use in the specialized "trashy seed" box.

All aerial mixes were combined into 1 mix for each treatment with the exception of antelope bitterbrush and fourwing saltbush which were kept separate for later use in the dribbler. The logistical constraints involved with separating the dribbler mixes on each treatment led to the decision to use a single dribbler mix (Table 5) over all blocks and seed mixes, except the untreated control. The seeding rate for the dribbler application was estimated at 2 kg/ha.

Rangeland Drill Seeding

The Jericho drill sites were seeded on 12 November, 1999. Four rangeland drills were used for seed application on the Jericho sites. Each drill was outfitted with 3 separate seed boxes to allow for the seed to be applied at different rates for each individual box. One of the additional seed boxes on each drill was specially designed for "trashy seed", such as sagebrush, which is difficult to feed through a typical drill. This box uses special augers to push the seed towards a center "pick-wheel" which rotates downward grabbing the seed and forcing it into the seeding tubes. The tubes from this box were disconnected from the disc assembly to allow the small-seeded sagebrush to fall onto the soil surface as recommended (USDA-ARS 2001). A smaller box was used to seed a separate mixture of shrubs with larger seeds (fourwing saltbush and antelope bitterbrush). This separate box allowed us to limit these shrub seeds to specific rows giving them a better chance of survival by reducing future competition with seeded grasses. The bitterbrush-fourwing shrub seed mix was seeded in rows 3 and 8 on a drill equipped with 10 seed-drops. The Native grass mixes were seeded through the remaining seed-drops. This configuration resulted in 1 row of shrubs between 4 rows of grass. For the ARS mix the smaller seed box was used to seed the forage kochia on the soil surface and to limit its seeding rate.

Each drill carried only the seed mix for which it was pre-calibrated. This was done in an attempt to avoid mistakes while re-calibrating drills between seeded treatments as well as to save time on the day of seeding. Calibration was accomplished by elevating and rotating the drive wheel of each drill while adjusting the openers and drive gears to obtain the desired rate for each seed mix. Four-wheel drive tractors were used to pull the drills through each block in a manner consistent with standard operations of the BLM. All drills used in this study were equipped with standard concave discs without depth regulator bands.

Aerial Seeding

Aerial seed application on the Mud Springs study sites took place on 19 November 1999. Although the BLM typically uses a fixed wing aircraft for its seeding operations, it was felt that a helicopter would be better suited to seed the relatively narrow study plots. This decision was based on the assumption that a helicopter would be more maneuverable and allow more precise application of different seed mixes on adjacent study plots. The use of the helicopter also allowed the convenience of putting a team member into the aircraft to direct operations from the air. The helicopter also facilitated on-site loading and changing of the seed mixes.

The helicopter was equipped with a gravity fed broadcast seeder which could be remotely opened and closed by the pilot from the cockpit of the aircraft. The broadcast seeder was calibrated prior to the day of the seeding by adjusting the opening at the bottom of the seed reservoir until the desired amount of seed was released in a specific amount of time. This amount was calculated to produce the desired seeding rate for a given airspeed and seeding swath width. The speed of the helicopter was adjusted at the time of seeding to produce the desired seeding rate for each seed mix, this varied from 74 to 124 km/hr.

Prior to the day of seeding, flight lines for each seeding pass were marked with flagged wooden laths. On the day of the seeding volunteers held large flourescent colored flags at each end of the seeding pass to give the pilot a clear line to follow. After the initial center pass 2 additional seeding passes were made on each side of the center pass. This created a continuous seeded swath (without skips) of about 55 meters. This left an unseeded area between each treatment to lessen the possibility of seed drift into adjacent plots.

Chaining

Following aerial seed application on the Mud Springs sites, the area was 1-way chained to help cover the seed. The chaining was completed using 2 crawler tractors (D8 and D9) pulling an “Ely” style chain. This type of chain has a section of railroad rail welded perpendicular to each link to increase soil disturbance and better cover seed. A mix of antelope bitterbrush and fourwing saltbush was applied to the area at this time using a seed dribbler attached to the outside track of each crawler tractor. Seed dribblers utilize a rubber tire in contact with the track of the crawler tractor to power a seeding mechanism which drops seed on to the crawler track. The seed falls on the ground in front of the track and is firmly pressed into the soil by the weight of the tractor (Plummer et al. 1968). Chaining was begun in late November but was interrupted by winter weather. In February the chaining resumed and the remaining blocks were finished. All seeded plots were chained and seeded with the dribbler mix, while a control plot was left undisturbed in each block.

Vegetation Sampling

Sampling of vegetation was accomplished using a 150 m baseline divided into 5, 30 m baseline transects within each treatment plot. One 30 m cross transect was centered and randomly placed perpendicular to each 30 m baseline. Twenty evenly spaced, 0.25 m^2 quadrats were read on each 30 m cross transect. These quadrats were placed with the base of each quadrat parallel to the cross transect, with the center of the quadrat directly in front of the placement mark (fig. 2).

Percent cover and nested frequency of vegetation, litter, rock, pavement, cryptogamic organisms, and bare ground were ocularly estimated within each quadrat. Aerial cover, nested frequency and density were determined for each species of grass, forb, and shrub using the same method. Modified Daubenmire cover classes (Bailey and Poulton 1968, Daubenmire 1959) were used with an additional cover class added to better estimate the lower cover numbers expected following fire and seeding. The cover classes are as follows: 1 = 0.01%-1%, 2 = 1.1%-5%, 3 = 5.1%-15%, 4 = 15.1%-25%, 5 = 25.1-50%, 6 = 50.1%-75%, 7 =

75.1%-95%, 8=95.1%-100%. Percent cover for each cover category or individual species is determined by summing all the midpoints for each cover class and dividing by the total number of quadrats for the site. Nested frequency is determined by dividing the quadrat into the following sub quadrats: 5 = 1% of the area, 4 = 5% of the area, 3 = 25% of the area, 2 = 50% of the area, and 1 = the remainder of the quadrat. Nested frequency scores were determined for each species and ground cover type according to the smallest sub-quadrat in which they were rooted. Sum of nested frequency (SNF) was calculated for each species and ground cover type by summing its scores in each quadrat over the entire site. This value gives a measurement of relative abundance for each species and ground cover type (Smith et. al. 1986, 1987; Mosley et. al. 1986). These values are especially useful in determining vegetation trend and changes in community composition through time. However, comparisons between treatments must be limited to characteristics or species measured in all treatments. In this study, sum of nested frequency for vegetation, rock, litter, pavement, bare ground, along with each individual species was measured in all treatments, therefore, between-treatment comparisons are limited to these variables.

Density measurements are the total number of individuals for each species found within the quadrats. Each of the perennial bunchgrasses were counted as 1 individual and abundant annual species with over 50 individuals were estimated. Shrub density was determined by using a 0.004 ha (1/100th acre) strip centered over the length of each 30 m cross transect. All shrub species rooted within this strip were counted. In addition, age classes for each individual shrub were determined according to Cole (1963). Density for each species and ground cover type was reported as average plants/0.25 m^2. This was obtained by dividing the total density per treatment plot by the total number of quadrats.

Vegetation was measured in late August of 2000 and 2001. In order to reduce bias due to changes in vegetation composition and size over the course of a growing season, vegetation was measured within the same week by the Utah Division of Wildlife Resources Range Crew as well as personnel from the Great Basin Research Center.

Other Sampling

Soil samples were collected for each treatment within each block. Samples were taken at each of the 6 baseline stakes by digging a 30-40 cm pit from which a thin slice of the profile was taken. Sub-samples were combined into 1 composite sample all of which were analyzed by the Brigham Young University (BYU) soil science laboratory to determine several basic physical and chemical properties. These properties included: P ppm, K ppm, organic matter %, pH, electrical conductivity, and texture.

Soil movement through wind and water erosion and deposition, was also measured using point or stake measurements of soil movement at the surface (Hadley and Lusby 1967, Haight 1977, Takei et. al.1981). 16 stakes were placed as measurement points within each treatment for a total of 80 erosion point measurements for each treatment. Stakes were located at 6 points along the center transect as well as at the end of each cross transect. The initial measurement was taken on the south side of the stake from the top of each stake to a washer placed around the stake resting on the surface of the soil. Additional measurements were taken periodically throughout the study and the difference between each measurement and the initial measurement averaged across the treatments to give an estimate of soil loss or accumulation across the sample area.

Weather data were collected at several sites. At the Jericho drill area, precipitation was recorded by a Campbell Scientific Inc. CR-10 micrologger (Campbell Scientific Inc., Logan, Ut). Precipitation data for the Mud Springs study area were obtained from the "Mud Springs" Remote Automated Weather Station (R.A.W.S.) which is located approximately 0.5 km from the aerial seeding sites.

Statistical Analysis

Mixed model analysis was used to determine significance of treatment effects. Treatment and year were considered fixed effects while block was considered a random effect. Differences among seed mixes for vegetation variables were determined using the Tukey-Kramer mean separation technique. Significant differences in soil variables and point erosion data were determined using the general linear model (GLM) technique with Tukey-Kramer used as a mean separation technique. All statistical analysis used an alpha level of 0.10 and was completed using the SAS and SYSTAT statistical software packages.

RESULTS

Precipitation for 2001 was less than half of the total for 2000 on the Jericho study area (Fig. 3) and little more than half of the 2000 total for the Mud Springs study area (Fig. 4). Although the yearly totals for 2001 were extremely low for both areas it is notable that early spring (March and April) precipitation was slightly higher than that recorded in 2000 on both the Jericho and Mud Springs study areas (Figs. 3,4).

Rangeland Drill Seeding - Vegetation

Vegetation means for the rangeland drill were lowered by the nearly equal failure of all seed mixes in the 2 southernmost blocks. These failures were not removed from the data set and subsequently have lowered overall means shown in our results. These values show a first year range of total mean cover between 13.6 and 18.8% cover and between 26.6 and 31.7% cover for the second year (Table 6). Annual plants dominated cover totals in both years ranging from 11-16% of total cover the first year, and from 17-30% of total cover the second year. The majority of annuals in both years were forbs.

The Native High seed mix had 2.7% seeded species cover the first year, and 7.7% seeded species cover the second year (Table 6). The ARS mix rose from 2.1% seeded species cover the first year to 6.9% seeded species cover in the second year (Table 6). BLM showed a seeded species cover of 2.0% in the first year and 7.2% the second year (Table 6). The Native Low mix's seeded species cover values were 0.8% for the first year and 2.6% for the second year (Table 6). Both the Native High and BLM mixes had significantly higher ($p < 0.10$) seeded cover than the Native Low mix in 2001 (Table 6). This proved to be the only significant difference in either year for seeded species cover in the drill seeding.

Three annual forbs dominated cover totals for the first year following treatment, these included: Russian thistle [*Salsola pestifer* A. Nels.] desert alyssum [*Alyssum desertorum* Stapf], and an annual species of gilia [*Gilia spp*. Ruiz & Pavon] (Table 6). The overall cover percentage for Russian thistle was greatly increased by its dominance in the 2 southernmost blocks. Cheatgrass [*Bromus tectorum* L.] was low in overall cover as were noxious weeds

(Table 6). Second year cover was again dominated by annual forbs including Russian thistle and desert alyssum (Table 6). *Gilia* spp. cover fell in the second year, while cheatgrass cover rose. Noxious weeds remained nearly absent in the second year (Table 6).

Average sum of nested frequency (SNF) values show a different view of the vegetation. Higher values here indicate higher relative abundance for each variable (Table 7). No significant difference ($p \geq 0.10$) was found for vegetation SNF in either year. Dominant annuals the first year were the same as those listed above. Russian thistle SNF was relatively lower than seen in the cover data due to its large crown diameter. In the second year larger crowned Russian thistle plants were replaced with abundant smaller plants of the same species. This only slightly raised cover numbers while considerably raising its SNF value (Tables 6, 7). Gilia accounted for a high percentage of first year vegetation SNF but dropped off to nearly nothing in the second year (Table 7). In contrast, desert alyssum accounted for only a minor percentage of vegetation SNF in the first year and rose to account for nearly double its first year percentage of vegetation SNF in the second year, filling the niche left by the disappearing gilia (Table 7).

Density, similar to SNF, was not as sensitive as cover to vegetation biomass increases due to the presence of large crowned plants such as Russian thistle. Total plant density ranged from 3.9 - 5.7 plants/0.25 m^2 in the first year and from 21.9 - 28.5 plants/0.25 m^2 in the second year for all treatments (Table 8). No significant difference ($p \geq 0.10$) among treatments was found for total density in either year. However, total perennial density both the BLM and Native High treatments was significantly higher ($p < 0.10$) than that of the Native Low and

Control treatments. (Table 8). The majority of the total density in both years was composed of annual species, mainly annual forbs. This annual component rose in the second year to account for over 90% of total density in all seeded treatments and nearly 99% of total density in the control. Dominant annuals in first year density estimates included: cheatgrass, desert alyssum, and *Gilia* spp. Second year annual density was similar in dominant species composition with the exception of Gilia which was replaced with Russian thistle in overall annual dominance. This was true across all treatments. Seeded species density ranged from 0.4 - 1.8 plants/0.25 m^2 the first year to 0.7 - 1.8 plants/0.25 m^2 in the second year (Table 8). The Native High treatment was significantly higher ($p < 0.10$) than the Native Low treatment in the first year and both Native High and BLM treatments were significantly higher ($p < 0.10$) than Native Low treatment the second year of the study (Table 8).

Bare ground and pavement dominated the ground cover percentage in both years (Table 9). However, as vegetation and litter cover increased the second year, bare ground cover decreased. SNF values for mean ground cover followed a similar pattern. As litter and vegetation increased and bare ground decreased, the site had better protection against soil loss through both wind and water erosion. This shift in ground cover is typical of an area following fire, and should continue in the future.

The 'Nezpar' variety of Indian ricegrass [*Stipa hymenoides* R. & S] proved to be the most successful species in both the Native High and the Native Low seed mixes (Tables 10, 11, 12). Indian ricegrass contributed more to the total seeded cover and total seeded density of both treatments in both years than all other seeded species combined. The ARS and BLM seed mixes both had significant contributions from crested wheatgrass, alfalfa [*Medicago sativa* L.], and tall wheatgrass [*Elymus elongatus* (Host) Runem] (Tables 10, 11, 12).

The ARS treatment included forage kochia seeded out of a separate seed box, however, this box fed into the drill furrow rather than directly to the soil surface. This may have buried seeds deeper than recommended and may have been a factor in its apparent failure (Table 13). The BLM mix contained fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.] which also did not emerge in either growing season (Table 13). This seed was taken from leftover seed, warehoused for several years, which may have been a factor in its failure. The Native High and Native Low mixes both showed measurable success in each year from all shrub species seeded (Table 13).

Rangeland Drill Seeding - Soil

Soil variables were not significantly different ($p < 0.10$) among treatments with the exception of organic matter which was higher in both the Native High and the control treatments than in the BLM treatment (Table 14). Differences in soil variables evidently did not account for variability in treatments. Block means for the drill seeding indicate the among-block variability which is statistically minimized by the complete randomized block design we employed. Blocks 4 and 5 had significantly higher ($p < 0.10$) amounts of sand when compared to all other blocks (Table 15). The higher sand percentage may explain the failure of all seeded treatments equally in these 2 blocks relative to all other drill seeding blocks. Seeds may have been buried too deep to emerge.

The drill seeding showed signs of slight erosion and deposition throughout the study although no significant differences (p $ 0.10) among seeded treatments or with the control were seen (Table 16). This suggests that all seeding treatments or the lack thereof had little effect on soil movement in the early stages of the rangeland drill study.

Aerial Seeding/Chaining - Vegetation

First year estimates of total cover for the aerial seeding/chaining sites ranged, without significant difference (p $ 0.10), from a low of 10.1% for the BLM treatment to a high of 10.8% for the control (Table 17). Second year total cover percent ranged again without significant difference (p $ 0.10) from a low for BLM of 19.8% to a high of 21.9% for the ARS treatment (Table 17). Unlike the drill seeding, perennials dominated total cover percentages in both years for nearly all of the aerial seeded treatments. In the second year, perennial cover of all seeded treatments except the Native High was significantly higher ($p < 0.10$) than the control (Table 17). Total cover of all annuals and of annual forbs on all seeded treatments were significantly lower ($p < 0.10$) than the control in the second year.(Table 17). After 2 years, annuals species dominated only the unseeded control.

Aerial seeded species cover in both years was not significantly different (p $ 0.10) among the seed mixes (Table 17). The ARS treatment had the highest seeded species cover in both years, 4.4% for the first year and 11.0% the second year (Table 17). Seeded species cover from the BLM treatment increased from 4% the first year to 10.7% the second year (Table 17). Seeded cover for the Native Low treatment ranged from 3.2% the first year to

9.0% the second year (Table 17). Seeded cover was lowest for the Native High treatment in both years with values of 2.8% the first year and 8.8% the second year (Table 17).

Two annual forbs dominated the annual cover during the first growing season following treatment, these included: desert alyssum and an annual species of Gilia. In the control these 2 annual forbs dominated the total cover in both years with 55% of the total cover in the first year and 63% of the total cover the second year. All other seeded treatments showed a large contribution from these 2 forbs with 31-44 % of total cover in the first year and 20-39% of total cover in the second year (Table 17). Average cover values for both cheatgrass and noxious weeds were very low for all the seeded treatments as well as the control in both years. Both species accounted for less than 1% of total cover for all seeded treatments and the control (Table 17).

Sum of nested frequency for vegetation ranged from 248.2 for the Native High treatment to 266.4 for the BLM, but did not differ significantly (p $ 0.10) the first year. The same was true the second year with SNF values ranging from 374 for the BLM treatment to 427 for the unseeded control (Table 18). Very low cheatgrass and knapweed SNF numbers were observed in each year (Table 18). Desert alyssum and *Gilia* spp. both showed large contributions to the total vegetation SNF the first year (Table 18). The second year desert alyssum increased its contribution while gilia dropped to near nothing on all treatments (Table 18).

Total density in the first year ranged from a low of 5.0 plants/0.25 m^2 in the ARS treatment to a high of 6.2 plants/0.25 m^2 in the control (Table 19). Total density more than tripled during the second year. The BLM treatment had the lowest total density of 17.4 plants/0.25 m^2 while the control had the highest second year total density value of 36.6 plants/0.25 m^2 (Table 19). Perennial plants dominated all seeded treatments the first year while the control was dominated by annuals. Second year density readings indicated a shift to annual dominance in all treatments. Perennial density only slightly increased the second year while annual density showed a dramatic increase (Table 19). Even with this dramatic second year increase in annual density, the control still showed significantly higher annual density than all other treatments except the Native High (Table 19). Most of the increase in annual density can be attributed to the marked increase of desert alyssum. This species accounted for 87-92% of annual density in the second year. Combined with cheatgrass these 2 annual species accounted for 92-97% of annual density the second year (Table 19).

Seeded species density was similar for all seeded treatments with no significant difference ($p \geq 0.10$) among them. First year values ranged from a low of 1.9 plants/0.25 m^2 for the Native High seed mix to a high of 2.4 plants/0.25 m^2 for the Native Low, ARS, and BLM seed mixes (Table 19). Density rose slightly in all treatments the second year to range from 3.1 plants/0.25 m^2 for the Native High seed mix to a high of 3.5 plants/0.25 m^2 for the Native Low seed mix (Table 19).

Mean ground cover and SNF measurements, similar to the drill seeding, were dominated by bare ground in both years (Table 20). As vegetation and litter increase in years following fire and seeding, bare ground begins to decrease, this pattern is evident here. The aerial seeding had higher cover of litter during the first year than the drill seeding, this is most likely due to the downed trees left on site following the chaining operation.

Crested wheatgrass was the most successful species in both the ARS and BLM mixes. This held true for cover, SNF, and density in both years (Tables 21-23). The ARS mix also showed notable contributions from alfalfa [*Medicago sativa* L.], Indian ricegrass, western wheatgrass [*Elymus smithii* (Rydb.) Gould] and a species of wheatgrass [*Elymus spp.* L.] which was unidentifiable to species. This species of wheatgrass dropped in cover, SNF, and density in the second year's reading due to further plant development leading to its proper identification (Tables 21-23). The BLM mix showed noticeable success from pubescent wheatgrass [*Elymus hispidus* (Opiz) Meld.], smooth brome, and tall wheatgrass (Tables 21-23). Both native mixes showed notable contributions from western wheatgrass and Indian ricegrass (Tables 21-23). The second year, bluebunch wheatgrass [*Elymus spicatus* (Pursh) Gould] rose to a more dominant role in the seeded species composition of both native treatments (Tables 21-23).

Although the dribbler mix of fourwing saltbush and antelope bitterbrush was seeded to all treatments, the success of these 2 species varied among seeded treatments (Table 24). This may have been due to an unequal distribution of the dribbler mix among treatments, as this could not be controlled and was not monitored at the time of chaining. Forage kochia in the ARS mix showed little success the first year and was completely absent the second year (Table 24). Wyoming big sagebrush was successful in both native seed treatments with the Native High treatment showing nearly double the density of the Native Low treatment in both years

(Table 24). This was expected as it was seeded at twice the rate of the Native Low mix (Tables 3-4).

Aerial Seeding/Chaining - Soil

Soil variables for all seed mixes and the control did not vary significantly (p $ 0.10) among treatments (Table 25). Blocks differed in various soil parameters (Table 26). Although no block seeding failures were seen in the aerial seeding, between-block variability in soil characteristics was expected in such a large scale study. This variability is accounted for in our experimental design and statistical model.

Point estimation of soil movement for the aerial seeding showed both slight erosion and deposition with no significant differences among seed mixes or with the control (Table 27). This suggests that seeding treatments or lack thereof had little or no effect on soil movement in the early part of this study.

DISCUSSION

Drill Seeding

Drill seeding is often favored in post fire rehabilitation because it provides a means of distributing and covering the seed in a single operation (Vallentine 1989). Compared to broadcast seeding, drill seeding generally favors infiltration and moisture storage, offers some wind protection, produces a more uniform stand, and results in stands reaching full production sooner (Vallentine 1989, Whisenant 1999). Seedling recruitment during either natural or artificial revegetation is a result of the number of seeds in favorable microsites, or “safe sites”, in the seedbed rather than the total number of available seeds (Harper et al. 1965, Young 1988).

One critical component of this includes proper seeding depth for each species in the mix. Drill seeding into softer seed beds can cause the seed to be buried too deeply, inhibiting seedling emergence and survival. The use of depth regulator bands on the drill disks helps, but only partially alleviates the problem of deep burial in excessively soft seedbeds (Vallentine 1989). The drills used in this study were not equipped with depth bands and the sandy soils of the Jericho drill seeding sites presented a soft seedbed.

It is hypothesized that the lack of depth bands along with the sandy soil condition at the Jericho sites resulted in deeper than optimum seeding depth. In addition, the significantly sandier soils in blocks 4 and 5 may have lead to the overall failure of all treatments on these blocks. Also the positioning of the drill rows perpendicular to the prevailing winds may have led to deposition in the drill rows and further burying of the seed.

Seeding depth is often a compromise of recommended seeding depths of all species used in a mix. If a failure to reach this optimum seeding depth is realized, certain seeds may be favored over others. Generally, the larger the seed the more energy reserves it has available and the deeper it can be buried and still emerge and succeed (Bloomquist and Lyon 1995, Hull 1966, Lawrence et al. 1991, USDA-NRCS 2001b). Our study showed high success of individual species with large seed size in all treatments. For example, the ARS seeded species success was almost completely dominated by moderate or large seeded species including crested wheatgrass and Indian ricegrass. The same held true for the BLM seeding which saw over 60% of the seeded density attributed to crested and tall wheatgrass in each year. Both native mixes showed a considerable contribution from ‘Nezpar’ Indian ricegrass in both years.

Indian ricegrass is unique in its ability to germinate and emerge from greater depths than most other seeded species (USDA-NRCS 2001b). Several studies have shown Indian ricegrass emergence from an average of 5 cm and up to 15 cm in sandy soils. (Kinsinger 1962, Young et al. 1969, 1983, 1994). This adaptation most likely developed in response to seed caching activities of small rodents (McAdoo et al. 1983). Indian ricegrass's ability to produce a coleoptile with tremendous elongation potential through sandy textured substrate most likely resulted in its success in the native and ARS mixes. Studies to determine actual seeding depth following treatment may help explain revegetation results (Winkel and Roundy 1991).

The relative failure of the Native Low treatment in the drill seeding is difficult to explain. Since individual species such as bluebunch wheatgrass and Indian ricegrass were seeded at identical rates as in the Native High mix, similar emergence was expected. Both mixes were taken from the same seed lots for each species and both drills were calibrated identically. This leaves the only other possibility that some other malfunction may have taken place while the seeding was in progress, possibly with the drill itself. It is difficult to ascertain where and if a problem occurred. Calculating the weight of seed mix used relative to the approximate acreage seeded would have corroborated or contradicted the calibrated seeding rate.

Aerial Seeding/Chaining

Broadcast seeding using aircraft is advantageous because of its increased speed and reduced costs (Whisenant 1999, Vallentine 1989). In addition, aerial seeding can be applied to almost any terrain. Disadvantages of broadcast seeding include: the lack of spacing and control over stand density, the loss of seed to predators, the lack of burial and resulting reduction in seed germination and establishment compared with drilling, and the requirement for higher seeding rates to compensate for reduced germination and increased predation. Seeding into prepared seedbeds, covering the seed, and firming the soil reduces these problems (Whisenant 1999). Although broadcast seeding by aircraft often costs less per acre than drill seeding, this cost is generally offset by the 50 to 75% more seed required with broadcasting (Vallentine 1989). This cost increase is magnified when using native species which often cost substantially more than exotic species. Additionally, native species often require higher seeding rates to insure success, further increasing overall costs.

Most aerial seedings utilize a fixed wing aircraft outfitted with a venturi flume mounted under the fuselage. Seed dropped into the flume is spread and carried away through the slipstream as it exits the flume (Vallentine 1989). For several reasons, including the plot sizes we employed, a helicopter was chosen for the aerial seeding in this study. Helicopters are capable of flying closer to the ground, flying at slower speeds, and are easier to land and refill with seed. This makes helicopters better adapted to smaller seedings. They are generally capable of producing a more uniform rate and distribution of seed across a study area, provided the wind is not over about 15 km/hr or turbulent and shifting (Vallentine 1989). The day of our seeding was hampered by slight winds while the helicopter was in flight. This may have resulted in seed drifting within plots, however, our design was such that between treatment drift was minimized.

Following aerial seeding, covering of seed by chaining is desirable in most situations and has proven advantageous in this area (Ott 2001,Ott et al. 2001). Most seed mixes use several species with differing seeding depth requirements. Chaining creates numerous micro sites and allows for shallow or deep planting depths (Stevens 1999a). This should allow more seeds to be placed in suitable micro sites and at appropriate planting depths. In addition, chaining leaves debris on the ground which can create run-in areas which interrupt continuous runoff pathways, thereby reducing the total amount of soil loss in the long term and across hillslopes (Davenport et al. 1998, Roundy and Vernon 1999). On different soil textures and parent materials both Gifford (1973) and Farmer et al. (1999) concluded that chainings with debris left in place produced less runoff and sediment when compared to unchained areas.

Unlike drill seeding, variable seeding depth from chaining favors no particular species or group of species. There was no single species which dominated over all others in the aerial seeding as did Indian ricegrass in the drill seeding. Similar to the drill seeding, all treatments showed more perennial vegetation and less annual vegetation following treatment. This again leads to the conclusion that seeding in some form is preferable to no seeding following fire.

All 3 vegetation measurements (cover, sum of nested frequency, and density) failed to show significant differences among seed mixes in both years of our study. These results indicate the ability of native seed mixes to establish and survive similarly to exotic seed mixes following proper seeding methods, seeding rates, and soil coverage from chaining.

CONCLUSIONS

Both the drill seeding and the aerial seeding demonstrated the ability of native species to establish in a semi-arid area using common seeding methods and proper seeding rates. By the end of the project both seeding techniques showed less annual and more perennial species in all treated areas when compared to the non-treated control. Although native mix results were similar to those seen in the BLM and ARS mixes, higher seeding rates and much higher costs were required to obtain these results. It was our intention that the scale of this project would allow better extrapolation of the results to large scale fire rehabilitation efforts using similar techniques. Finally, it is important to note that conclusions drawn in the first years after rehabilitation projects are often preliminary. Soil stabilization, resistance to weed invasion, and protection of life are a few of the preliminary goals of post fire rehabilitation administered by emergency fire rehabilitation funds. Long term goals of these treatments focus more on continued stability and ecosystem functionality. Continued monitoring is planned for this project, the results of which will better measure the long term success of each treatment.

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APPENDIX A

Tables

Table 1. Bulk seeding rates and costs for Bureau of Land Management (BLM) seed mixes used for fire rehabilitation in Tintic Valley, Utah.

Species	Pure Live Seed (%)	Rate (kg/ha)		Cost ($/kg)		Cost ($/ha)	
		Drill	Aerial	Drill	Aerial	Drill	Aerial
Crested wheatgrass - Hycrest	85	2.2	4.5	0.61	0.52	1.38	2.33
Bluebunch wheatgrass - Goldar	86	-	3.0	-	2.27	-	6.80
Pubescent wheatgrass - Luna	91-92	2.2	3.0	0.68	0.64	1.53	1.90
Russian wildrye - Bozoisky	76-96	2.2	3.0	1.45	1.30	3.26	3.88
Smooth brome - Lincoln	81	-	3.0	-	0.24	-	0.72
Tall wheatgrass - Alkar	83	2.2	3.0	0.70	0.70	1.58	2.10
Western wheatgrass - Aribba	88	1.1	-	1.86	-	2.09	-
Alfalfa - Innoculated - Ladak	92	0.6	-	0.88	-	0.49	-
Fourwing saltbush	32	0.6	-[1]	2.83	-[1]	1.59	-[1]
Antelope bitterbrush	-	-	-[1]	-	-[1]	-	-[1]
TOTAL	-	11.1	19.5	-	-	11.90	17.74

[1]Included in dribbler mix

Table 2. Bulk seeding rates and costs for Agricultural Research Service (ARS) seed mixes used for fire rehabilitation in Tintic Valley, Utah.

Species	Pure Live Seed (%)	Rate (kg/ha)		Cost ($/kg)		Cost ($/ha)	
		Drill	Aerial	Drill	Aerial	Drill	Aerial
Siberian wheatgrass - Vavilov	89	1.9	3.8	0.65	0.65	1.22	2.44
Hybrid crested wheatgrass - CD II	93	1.8	3.6	0.95	0.95	1.72	3.44
Russian wildrye - Bozoisky	76	1.5	3.0	1.37	1.37	2.04	4.07
Thickspike wheatgrass - Critana	93	0.6	1.2	2.77	2.77	1.67	3.34
Bluebunch wheatgrass - Secar	89	1.3	2.5	2.71	2.71	3.41	6.82
Western wheatgrass - Rosana	93	1.2	2.4	2.75	2.75	3.31	6.62
Indian ricegrass - Rimrock	92	0.6	1.2	4.18	4.18	2.54	5.09
Alfalfa - rangelander	56	1.5	3.0	0.50	0.50	0.74	1.49
Forage kochia - Immigrant	71	0.4	0.8	3.96	3.96	1.55	3.10
Fourwing saltbush	32	-	-[1]	2.50	-[1]	-	-[1]
Antelope bitterbrush	-	-	-[1]	3.83	-[1]	-	-[1]
TOTAL	-	10.7	23.7	-	-	18.20	36.41

[1]Included in dribbler mix

Table 3. Bulk seeding rates and costs for Native high diversity seed mixes used for fire rehabilitation in Tintic Valley, Utah.

Species	Pure Live Seed (%)	Rate (kg/ha)		Cost ($/kg)		Cost ($/ha)	
		Drill	Aerial	Drill	Aerial	Drill	Aerial
Bluebunch wheatgrass - Whitmar	-	2.2	4.5	3.40	3.40	7.61	15.23
Bluebunch wheatgrass - Goldar	86	2.2	4.5	2.27	2.27	5.10	10.20
Western wheatgrass - Rosana	-	2.2	3.0	1.91	1.91	4.28	5.70
Indian ricegrass - Nezpar	-	2.2	3.0	5.07	5.07	11.37	15.16
Squirreltail - VNS	76-78	2.2	3.0	8.17	8.17	18.32	24.43
Needle and thread - VNS	88	2.2	3.0	1.44	10.44	23.41	31.21
Basin wildrye - Magnar	86	2.2	3.0	3.00	3.00	6.72	8.96
Sandberg bluegrass	85	2.2	3.0	3.05	3.05	6.84	9.12
Wyoming big sagebrush	14	2.2	3.0	1.59	1.59	3.56	4.75
Fourwing saltbush	32	1.1	-[1]	2.50	-[1]	2.80	-[1]
Antelope bitterbrush	-	1.1	-[1]	3.83	-[1]	4.30	-[1]
TOTAL	-	22.4	32.1	-	-	94.31	124.76

[1]Included in dribbler mix

Table 4. Bulk seeding rates and costs for Native low diversity seed mixes used for fire rehabilitation in Tintic Valley, Utah.

Species	Pure Live Seed (%)	Rate (kg/ha)		Cost ($/kg)		Cost ($/ha)	
		Drill	Aerial	Drill	Aerial	Drill	Aerial
Bluebunch wheatgrass - Whitmar	-	2.2	4.5	3.40	3.40	7.61	15.23
Bluebunch wheatgrass - Goldar	86	2.2	4.5	2.27	2.27	5.10	10.20
Western wheatgrass - Rosana	-	1.1	3.0	1.91	1.91	2.14	5.70
Indian ricegrass - Nezpar	-	2.2	3.0	5.07	5.07	11.37	15.16
Sandberg bluegrass	85	-	1.5	-	3.05	-	4.56
Wyoming big sagebrush	14	1.1	1.5	1.59	1.59	1.78	2.38
Fourwing saltbush	32	1.1	-[1]	2.50	-[1]	2.80	-[1]
Antelope bitterbrush	-	1.1	-[1]	3.83	-[1]	4.30	-[1]
TOTAL	-	11.2	20.2	-	-	35.10	53.22

[1]Included in dribbler mix

Table 5. Bulk seeding rates and costs for Dribbler seed mix used on all aerial seeding plots in Tintic Valley, Utah.

Species	PLS (%)	Rate(kg/ha)	Cost ($/kg)	Cost ($/ha)
Fourwing saltbush	32	1.1	2.50	2.75
Antelope bitterbrush	-	1.1	3.83	4.21
TOTAL	-	2.2	-	6.96

Table 6. Vegetation cover (%) for 2 years after drill seeding in Tintic Valley, Utah.

Vegetation Characteristics	ARS 2000	ARS 2001	BLM 2000	BLM 2001	Native Low 2000	Native Low 2001	Native High 2000	Native High 2001	Control 2000	Control 2001
	-------------------- Cover (%) --------------------									
Total	18.8	31.6	18.2	27.9	16.0	30.9	15.7	26.6	13.6	31.7
Total perennial	3.0	7.5ab[1]	3.1	8.3ab	2.1	3.9b	4.0	8.9a	0.9	1.4b
Total annual	15.8	24.2	15.0	19.6	14.0	29.9	11.7	17.7	12.7	30.3
Perennial grass	1.4	5.1ab	1.9	6.7a	0.9	2.8b	2.8	8.0a	0.1	0.2b
Annual grass	0.50	2.2	0.5	1.6	0.6	2.6	0.6	1.8	0.4	1.8
Perennial forb	1.5	2.3	1.2	1.6	1.1	1.1	1.3	0.9	0.9	1.3
Annual forb	15.4	22.0	14.5	18.0	13.3	24.3	11.0	15.9	12.3	28.6
Seeded species	2.1	6.9ab	2.0	7.2a	0.8	2.6b	2.7	7.7a	-	-
Cheatgrass	0.5	2.2	0.5	2.6	0.6	2.6	0.6	1.8	0.4	1.8
Desert alyssum	1.6	10.7	2.2	7.9	1.6	9.4	1.4	8.6	1.2	12.3
Gilia spp.	5.3	0.1	6.2	0.3	6.4	0.2	5.7	0.2	4.7	0.3
Russian thistle	8.1	10.6	6.0	9.5	5.0	13.4	3.7	10.1	5.9	15.1
Noxious weed	0	<0.1	0	0	0	0	0	0	0	<0.1

[1]Values for each year with different letters are significantly different at $p < 0.10$

Table 7. Sum of nested frequency for vegetation and selected species for 2 years following drill seeding in Tintic Valley, Utah.

Vegetation Characteristics	Seed Mix									
	ARS		BLM		Native Low		Native High		Control	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Sum of Nested Frequency -------------------									
Vegetation	252.2	419.4	270.4	403.4	225.6	401.8	270.8	408.6	211.6	426.6
Cheatgrass	39.4	111.2	37.8	114.6	41.4	134.2	44.0	120.4	42.4	114
Desert alyssum	65.0	271.8	85.0	263	57.0	254	64.6	295	72.4	292.6
Gilia spp.	150.0	16.8	172.8	17.2	158.4	13.6	155.0	16.6	154.0	16.6
Russian thistle	23.6	192.6	17.2	164.4	13.6	201.4	16.6	179.6	16.6	209.2
Noxious weed	0	0	0	0	0	0	0	0	0	.8

[1]Values for each year with different letters are significantly different at $p < 0.10$

Table 8. Vegetation density (plants/0.25 m^2) for 2 years after drill seeding in Tintic Valley, Utah.

Vegetation Characteristics	Seed Mix									
	ARS		BLM		Native Low		Native High		Control	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Density (Plants/0.25 m^2) -------------------									
Total	4.4	28.5	5.7	24.9	4.0	23.8	5.4	21.9	3.9	27.2
Total perennial	1.3ab[1]	1.4ab	1.8a	2.3a	0.7b	1.1b	2.1a	2.3a	0.3b	0.4b
Total annual	3.1	27.1	3.9	22.6	3.4	22.8	3.2	19.6	3.6	26.8
Perennial grass	0.9abc	1.1bc	1.5ab	2.0b	0.4bc	0.7c	1.8a	1.9b	<0.1c	<0.1c
Annual grass	0.3	3.0	0.3	3.3	0.3	3.4	0.4	2.7	0.4	2.9
Perennial forb	0.4	0.3	0.4	0.3	0.2	0.4	0.3	0.4	0.3	0.4
Annual forb	2.8	24.1	3.6	19.3	3.1	19.4	2.9	16.9	3.2	23.9
Seeded species	1.1ab	1.3ab	1.5ab	1.8a	0.4b	0.7b	1.8a	1.8a	-	-
Cheatgrass	0.3	3.0	0.3	3.3	0.3	3.4	0.4	2.8	0.4	2.9
Desert alyssum	0.7	10.4	1.0	11.1	0.7	8.7	0.6	8.9	0.9	11.4
Gilia spp.	1.9	0.2	2.5	0.3	2.2	0.5	2.1	0.6	2.0	0.6
Russian thistle	0.1	13.1	0.1	7.5	0.1	9.3	0.1	7.0	0.1	11.5
Noxious weed	0	0	0	0	0	0	0	0	0	<0.1

[1]Values for each year with different letters are significantly different at $p < 0.10$

Table 9. Ground cover type for 2 years after drill seeding in Tintic Valley, Utah.

Ground Cover Type	Seed Mix									
	ARS		BLM		Native Low		Native High		Control	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Vegetation cover (%)	20.3	32.3	19.0	28.8	16.7	32.0	17.1	31.7	14.6	31.6
Vegetation SNF[1]	252.2	419.4	270.4	403.4	225.6	401.8	270.8	408.6	211.6	426.6
Litter cover (%)	1.4	17.5a[2]	1.7	12.9ab	1.4	11.5ab	1.5	11.7ab	1.7	10.1b
Litter SNF	128.2	421.8	125.8	401.8	134.8	400.6	140.0	406.8	140.2	361.4
Rock cover (%)	1.1	2.1	1.4	1.3	1.4	1.3	1.6	1.0	1.3	1.2
Rock SNF	94.4	96.6	124.4	131.4	121.4	117.6	123.2	97.2	86.8	110.2
Pavement cover (%)	27.9	12.9	30.7	12.7	30.7	14.9	32.8	12.2	38.1	19.1
Pavement SNF	437.8	380.4	446.4	402.0	454.4	422.4	440.6	394.2	464.2	405.0
Bare ground cover (%)	62.4	43.7	55.6	51.2	58.7	47.6	54.3	47.0	54.5	44.1
Bare ground SNF	491.2	436.0	482.6	472.6	486.8	463.2	468.6	460.4	483.0	444.6

[1] SNF = Sum of Nested Frequency

[2] Values for each year with different letters are significantly different at $p < 0.10$

Table 10. Herbaceous cover (%) for seeded species for 2 years after drill seeding in Tintic Valley, Utah.

Herbaceous Seeded Species	Seed Mix							
	ARS		BLM		Native Low		Native High	
	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Cover (%) --------------------							
Crested wheatgrass	0.6	3.1	0.5	2.3	-	-	-	-
Tall wheatgrass	-	-	0.8	2.2	-	-	-	-
Western wheatgrass	<0.1	0.1	0.2	0.1	0.2	0.2	<0.1	0.9
Bluebunch wheatgrass	<0.1	<0.1	-	-	0.1	0.5	0.3	0.7
Wheatgrass spp.[1]	0.3	0.3	0.1	0.5	<0.1	0.2	0.2	<0.1
Pubescent wheatgrass	-	-	0.1	1.0	-	-	-	-
Basin wildrye	-	-	-	-	-	-	<0.1	<0.1
Russian wildrye	0.1	0.1	<0.1	1.0	-	-	-	-
Alfalfa	0.8	2.1	0.3	0.1	-	-	-	-
Indian ricegrass	0.4	1.2	-	-	0.5	1.7	2.1	5.4
Sandberg bluegrass	-	-	-	-	-	-	<0.1	<0.1
Squirreltail	-	-	-	-	-	-	<0.1	0.2
Needle and thread	-	-	-	-	-	-	<0.1	0.4
TOTAL	2.1	6.9	2.0	7.2	0.8	2.6	2.7	7.7

[1]Unidentifiable to species

Table 11. Herbaceous seeded species sum of nested frequency for 2 years after drill seeding in Tintic Valley, Utah.

Herbaceous Seeded Species	Seed Mix							
	ARS		BLM		Native Low		Native High	
	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Sum of Nested Frequency -------------------							
Crested wheatgrass	37.6	69.6	46	70.6	-	-	-	-
Tall wheatgrass	-	-	67.4	63.8	-	-	-	-
Western wheatgrass	0	7	12.6	9	4.6	9	4.2	33.2
Bluebunch wheatgrass	2.8	3.8	-	-	12.2	17.4	29.6	36.4
Wheatgrass spp.[1]	29.6	14	5.8	12.6	3.4	5.2	22.6	2.2
Pubescent wheatgrass	-	-	12.4	32.2	-	-	-	-
Basin wildrye	-	-	-	-	-	-	1.4	0.8
Russian wildrye	2	8	0.4	20	-	-	-	-
Alfalfa	39.2	39.2	18.6	6	-	-	-	-
Indian ricegrass	27.2	36.6	-	-	28.2	34	120.6	107.8
Sandberg bluegrass	-	-	-	-	-	-	1.4	6.2
Squirreltail	-	-	-	-	-	-	3.4	8
Needle and thread	-	-	-	-	-	-	0	20
TOTAL	138.4	178.2	163.2	214.2	48.4	65.6	183.2	214.6

[1]Unidentifiable to species

Table 12. Herbaceous seeded species density (plants/0.25 m^2) for 2 years after drill seeding in Tintic Valley, Utah.

Herbaceous Seeded Species	Seed Mix							
	ARS		BLM		Native Low		Native High	
	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Density (plants/0.25 m^2) -------------------							
Crested wheatgrass	0.4	0.6	0.4	0.6	-	-	-	-
Tall wheatgrass	-	-	0.6	0.5	-	-	-	-
Western wheatgrass	<0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.4
Bluebunch wheatgrass	<0.1	<0.1	-	-	0.1	0.1	0.4	0.3
Wheatgrass spp.[1]	0.3	0.1	0.1	0.2	<0.1	0.2	0.2	<0.1
Pubescent wheatgrass	-	-	0.1	0.3	-	-	-	-
Basin wildrye	-	-	-	-	-	-	<0.1	<0.1
Russian wildrye	<0.1	0.1	<0.1	0.1	-	-	-	-
Alfalfa	0.3	0.2	0.1	<0.1	-	-	-	-
Indian ricegrass	0.2	0.2	-	-	0.2	0.3	1.1	0.9
Sandberg bluegrass	-	-	-	-	-	-	<0.1	<0.1
Squirreltail	-	-	-	-	-	-	<0.1	0.1
Needle and thread	-	-	-	-	-	-	<0.1	0.1
TOTAL	1.1	1.3	1.5	1.8	0.5	0.7	1.8	2.1

[1]Unidentifiable to species

Table 13. Seeded shrub density (plants/ha) for 2 years following drill seeding in Tintic Valley, Utah.

Shrub Seeded Species	Seed Mix ARS 2000	ARS 2001	BLM 2000	BLM 2001	Native Low 2000	Native Low 2001	Native High 2000	Native High 2001
	-------------------- Density (Plants/ha) -------------------							
Forage kochia	0	0	-	-	-	-	-	-
Wyoming big sagebrush	-	-	-	-	19.4	22.4	62.8	49.3
Fourwing saltbush	-	-	0	0	9.0	13.5	49.3	44.8
Antelope bitterbrush	-	-	-	-	22.4	40.4	165.9	156.9

Table 14. Soil variables (0-40 cm) 2 years after fire and 1 year after drill seeded to different mixes on a Wyoming big sagebrush community in Utah.

Seed Mix	Soil Analysis Parameter							
	P(ppm)	K(ppm)	OM (%)	pH	EC (dS\M)	Sand (%)	Clay (%)	Silt (%)
ARS	8.8	327.0	1.2ab[1]	7.8	0.6	56.4	18.3	25.3
BLM	6.5	271.4	1.1b	7.8	0.5	57.5	18.3	24.2
Native Low	7.6	323.8	1.3ab	7.8	0.6	57.5	18.5	24.0
Native High	9.2	335.4	1.3a	7.9	0.6	57.7	17.0	25.3
Control	7.5	363.5	1.3a	7.9	0.6	59.0	16.3	24.7

[1]Column values with different letters are significantly different at $p < 0.10$

Table 15. Soil variables (0-40 cm) 2 years after fire and 1 year after drill seeded to different mixes on a Wyoming big sagebrush community in Utah.

Blocks	Soil Analysis Parameter							
	P(ppm)	K(ppm)	OM (%)	pH	EC (dS\M)	Sand (%)	Clay (%)	Silt (%)
Block 1	6.9ab[1]	313.0	1.4a	7.8b	0.5b	51.2c	21.6a	27.2a
Block 2	9.5a	321.3	1.5a	7.8ab	0.5b	53.8bc	20.0ab	26.2a
Block 3	9.7a	303.4	1.3a	7.8ab	0.6ab	55.8b	16.8bc	27.5a
Block 4	5.5b	321.9	0.8b	8.0a	0.6ab	64.5a	15.7c	19.8b
Block 5	7.9ab	361.6	1.2a	7.8b	0.7a	62.8a	14.4c	22.8b

[1]Column values with different subscript letters are significantly different at $p < 0.10$

Table 16. Erosion point differences (mm) measured periodically for 2 years after drill seeding in Tintic Valley, Utah.

Seed Mix	Point measurement differences (mm)
	----------0----------
ARS	-0.7[1,2]
BLM	+0.5
Native Low	+1.9
Native High	-0.8
Control	-0.5

[1]No values were significantly different at p $ 0.10
[2] Positive values indicate deposition, negative values indicate erosion

Table 17. Vegetation cover (%) for 2 years after aerial seeding in Tintic Valley, Utah.

Vegetation Characteristics	Seed Mix									
	ARS		BLM		Native Low		Native High		Control	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Cover (%) --------------------									
Total	10.1	21.9	10.1	19.8	10.3	21.7	10.1	20.0	10.8	21.4
Total perennial	6.4	13.8a[1]	6.3	14.7a	5.1	11.6a	4.8	10.9ab	3.8	6.2b
Total annual	3.8	8.1b	3.8	5.1b	5.2	10.0b	5.3	9.1b	7.0	15.2a
Perennial grass	4.8	12.0	5.2	13.5	3.6	9.9	3.3	9.4	1.8	4.1
Annual grass	0.2	0.3	0.1	0.2	0.2	0.4	0.8	0.3	0.1	0.5
Perennial forb	1.5	1.8	1.1	1.2	1.6	1.8	1.5	1.6	2.0	2.2
Annual forb	3.6	7.8b	3.7	4.9b	5.0	9.6b	5.2	8.9b	6.9	14.7a
Seeded species	4.4	11.0	4.0	10.7	3.2	9.0	2.8	8.8	-	-
Cheatgrass	0.1	0.3	0.1	0.2	0.2	0.4	0.1	0.3	0.1	0.5
Desert alyssum	1.6	8.3b	1.3	4.1b	1.8	8.3b	1.9	7.8b	3.7	13.4a
Gilia spp.	1.6	0.1	1.9	<0.1	2.6	<0.1	2.6	<0.1	2.2	<0.1
Noxious weed	0	0	0	<0.1	<0.1	0.1	0.1	<0.1	<0.1	0.1

[1]Values for each year with different letters are significantly different at $p < 0.10$

Table 18. Sum of nested frequency for vegetation and selected species for 2 years after aerial seeding in Tintic Valley, Utah.

Vegetation Characteristics	Seed Mix									
	ARS		BLM		Native Low		Native High		Control	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Sum of nested frequency -------------------									
Vegetation	253.0	379.4	266.4	374.0	259.2	396.6	248.2	394.4	260.8	427.0
Cheatgrass	12.8	32	5.0	20.2	7.8	30.2	4.2	20.2	13.6	45.6
Desert alyssum	64.6	301.4b	65.8	289.6b	72.8	327.2ab	84.6	340.8ab	148.8	407.8a
Gilia spp.	59.8	1.4	75.6	0	91.4	0.6	104.0	0.2	97.8	0.6
Noxious weed	0.2	0	0.2	0.4	0.4	0.2	0.2	0.2	0.2	0.2

[1]Values for each year with different letters are significantly different at $p < 0.10$

Table 19. Vegetation density (plants/0.25 m^2) for 2 years after aerial seeding in Tintic Valley, Utah.

Vegetation Characteristics	Seed Mix									
	ARS		BLM		Native Low		Native High		Control	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Density (plants/0.25 m^2) -------------------									
Total	5.0	23.3ab[1]	5.5	17.4b	5.4	22.5ab	5.1	23.3ab	6.2	36.6a
Total perennial	3.5	4.5	3.7	4.6	3.3	4.7	2.8	4.0	2.0	3.3
Total annual	1.5	18.8b	1.9	12.9b	2.0	17.8b	2.3	19.4ab	4.2	33.3a
Perennial grass	2.7	3.6	3.0	3.9	2.6	3.7	2.1	3.2	1.0	2.3
Annual grass	0.2	1.0	<0.1	0.3	0.1	0.9	0.1	0.4	0.2	0.9
Perennial forb	0.8	0.9	0.6	0.7	0.7	1.0	0.7	0.7	1.0	1.0
Annual forb	1.3	17.7	1.8	12.5	2.0	16.9	2.2	18.9	4.0	32.5
Seeded species	2.4	3.3	2.4	2.5	2.4	3.5	1.9	3.1	-	-
Cheatgrass	0.2	1.0	<0.1	0.3	0.1	0.9	0.1	0.4	0.2	0.9
Desert alyssum	0.7	17.2b	0.8	11.8b	0.9	15.5b	1.0	17.5b	2.7	30.8a
Gilia spp.	0.6	<0.1	0.9	<0.1	1.0	<0.1	1.2	<0.1	1.1	<0.1
Noxious weed	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

[1]Values for each year with different letters are significantly different at $p < 0.10$

Table 20. Ground cover type for 2 years after aerial seeding in Tintic Valley, Utah.

Ground Cover Type	Seed Mix									
	ARS		BLM		Native Low		Native High		Control	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Vegetation cover (%)	10.6	23.1	11.1	21.7	11.0	23.2	10.2	22.6	11.9	22.6
Vegetation SNF[1]	253.0	379.4	266.4	374.0	259.2	396.6	248.2	394.4	260.8	427.0
Litter cover (%)	18.5	24.8	15.8	22.6	15.4	22.4	14.2	21.5	16.0	18.7
Litter SNF	371.2	421.4	339.8	426.6	333.2	412.2	313.6	402.6	352.0	425.0
Rock cover (%)	3.5	3.5	3.9	2.6	2.5	1.5	2.4	2.2	1.3	1.3
Rock SNF	158.6	129.0	167.8	126.4	121.8	97.0	105.6	111.0	104.8	102.0
Pavement cover (%)	14.1	6.3	12.3	7.2	11.9	6.7	11.3	6.1	12.3	8.8
Pavement SNF	365.0	338.8	330.4	299.2	346.4	336.8	327.8	313.8	416.2	372.2
Bare ground cover (%)	58.3	52.3	60.4	54.5	62.3	54.2	58.6	56.7	62.3	57.5
Bare ground SNF	472.6	450.4	480.2	459.8	474.0	456.0	456.2	469.0	484.4	472.8

[1] SNF = Sum of Nested Frequency

[2] No values for each year were significantly different at $p < 0.10$

Table 21. Herbaceous seeded species cover (%) for 2 years after aerial seeding in Tintic Valley, Utah.

Herbaceous Seeded Species	Seed Mix							
	ARS		BLM		Native Low		Native High	
	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Cover (%) -------------------							
Crested wheatgrass	1.7	5.8	1.4	4.3	-	-	-	-
Tall wheatgrass	-	-	0.3	1.9	-	-	-	-
Western wheatgrass	0.5	1.7	-	-	1.7	1.8	1.2	2.3
Bluebunch	0.1	0.6	0.1	0.6	0.3	4.3	0.3	2.9
Wheatgrass spp.[1]	1.2	0.8	0.3	0.2	0.1	0.2	0.1	0.1
Pubescent wheatgrass	-	-	1.1	1.2	-	-	-	-
Basin wildrye	-	-	-	-	-	-	<0.1	0.4
Russian wildrye	0.2	0.5	0.2	0.4	-	-	-	-
Alfalfa	0.3	0.3	-	-	-	-	-	-
Indian ricegrass	0.5	1.4	-	-	0.9	1.7	0.8	1.6
Sandberg bluegrass	-	-	-	-	0.1	1.0	0.2	0.5
Smooth brome	-	-	0.6	2.0	-	-	-	-
Squirreltail	-	-	-	-	-	-	0.1	0.5
Needle and thread	-	-	-	-	-	-	<0.1	0.4
TOTAL	4.4	11.0	4.0	10.7	3.2	9.0	2.9	8.8

[1]Unidentifiable to species

Table 22. Herbaceous seeded species sum of nested frequency for 2 years after aerial seeding in Tintic Valley, Utah.

Herbaceous Seeded Species	Seed Mix							
	ARS		BLM		Native Low		Native High	
	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Sum of Nested Frequency -------------------							
Crested wheatgrass	54.8	104.6	79.2	97.2	-	-	-	-
Tall wheatgrass	-	-	16.8	37.2	-	-	-	-
Western wheatgrass	26.0	54.2	-	-	70.0	63.6	55.8	78.6
Bluebunch wheatgrass	7.4	24.0	7.4	15.6	21.6	100.2	32.2	76.2
Wheatgrass spp.[1]	38	19.4	12.8	5.2	6.2	5.6	9.4	2.6
Pubescent wheatgrass	-	-	48.6	25.2	-	-	-	-
Basin wildrye	-	-	-	-	-	-	2.4	8.2
Russian wildrye	4.0	13.4	9.4	8.8	-	-	-	-
Alfalfa	26.6	20.4	-	-	-	-	-	-
Indian ricegrass	24.0	24.2	-	-	58.6	42.4	47.2	31.0
Sandberg bluegrass	-	-	-	-	12.8	42.2	15.4	33.0
Smooth brome	-	-	40.6	63.0	-	-	-	-
Squirreltail	-	-	-	-	-	-	11.4	29.0
Needle and thread	-	-	-	-	-	-	2.0	15.8
TOTAL	180.8	260.2	214.8	252.2	169.2	254.0	175.8	274.4

[1]Unidentifiable to species

Table 23. Herbaceous seeded species density (plants/0.25 m^2) for 2 years after aerial seeding in Tintic Valley, Utah.

Herbaceous Seeded Species	Seed Mix							
	ARS		BLM		Native Low		Native High	
	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Density (plants/0.25 m^2) -------------------							
Crested wheatgrass	0.9	1.3	0.9	1.0	-	-	-	-
Tall wheatgrass	-	-	0.2	0.3	-	-	-	-
Western wheatgrass	0.3	1.1	-	-	1.4	1.4	0.8	1.3
Bluebunch wheatgrass	0.1	0.2	0.1	0.2	0.2	1.3	0.3	0.8
Wheatgrass spp.[1]	0.7	0.3	0.2	0.1	0.1	0.1	0.1	0.1
Pubescent wheatgrass	-	-	0.5	0.2	-	-	-	-
Basin wildrye	-	-	-	-	-	-	<0.1	0.1
Russian wildrye	<0.1	0.1	0.1	0.1	-	-	-	-
Alfalfa	0.2	0.1	-	-	-	-	-	-
Indian ricegrass	0.2	0.2	-	-	0.6	0.3	0.4	0.2
Sandberg bluegrass	-	-	-	-	0.1	0.5	0.2	0.3
Smooth brome	-	-	0.5	0.7	-	-	-	-
Squirreltail	-	-	-	-	-	-	0.1	0.2
Needle and thread	-	-	-	-	-	-	<0.1	0.1
TOTAL	2.5	3.3	2.4	2.5	2.4	3.5	1.9	3.1

[1]Unidentifiable to species

Table 24. Seeded shrub density (plants/ha) for 2 years following aerial seeding in Tintic Valley, Utah.

Shrub Seeded Species	Seed Mix							
	ARS		BLM		Native Low		Native High	
	2000	2001	2000	2001	2000	2001	2000	2001
	-------------------- Density (plants/ha) -------------------							
Forage kochia	4.5	0	-	-	-	-	-	-
Wyoming big sagebrush	-	-	-	-	71.7	116.6	125.6	215.2
Fourwing saltbush	44.8	17.9	4.5	22.4	44.8	35.9	89.7	76.2
Antelope bitterbrush	31.4	13.5	31.4	22.4	35.9	26.9	62.8	62.8

Table 25. Soil variables (0-40 cm) 2 years after fire and 1 year after aerial seeded to different mixes on a pinyon-juniper community in Utah.

Seed Mix	Soil Analysis Parameter							
	P(ppm)	K(ppm)	OM (%)	pH	EC (dS\M)	Sand (%)	Clay (%)	Silt (%)
ARS	8.9	265.6	3.1	7.4	0.8	46.7	24.9	28.4
BLM	9.7	281.6	2.8	7.4	0.8	48.5	22.9	28.6
Native Low	9.4	264.3	2.6	7.4	0.8	47.8	24.1	28.2
Native High	9.0	231.0	2.7	7.4	0.7	47.8	23.2	29.0
Control	13.0	251.5	2.7	7.4	0.8	47.1	23.8	29.1

[1]Column values with different subscript letters are significantly different at $p < 0.10$

Table 26. Soil variables (0-40 cm) 2 years after fire and 1 year after aerial seeded to different mixes on a pinyon-juniper community in Utah.

Blocks	Soil Analysis Parameter							
	P(ppm)	K(ppm)	OM (%)	pH	EC (dS\M)	Sand (%)	Clay (%)	Silt (%)
Block 1	6.3b[1]	217.0	3.2a	7.3b	0.7	46.6bc	24.9ab	28.5b
Block 2	17.8a	249.0	3.2ab	7.5ab	0.8	41.2c	27.5a	31.3ab
Block 3	9.1b	291.8	2.4b	7.4ab	0.7	42.9c	24.2ab	32.9a
Block 4	6.8b	282.9	2.5ab	7.4ab	0.8	55.8a	21.1b	23.7c
Block 5	10.0ab	253.4	2.7ab	7.5a	0.8	51.9ab	21.1b	27.0bc

[1]Column values with different subscript letters are significantly different at $p < 0.10$

Table 27. Erosion point differences (mm) measured periodically for 2 years after aerial seeding in Tintic Valley, Utah.

Treatment	Point measurement differences (mm)
	----------0----------
ARS	-1.1[1,2]
BLM	+0.2
Native Low	+0.4
Native High	-2.0
Control	+0.4

[1]No values were significantly different at $p < 0.10$
[2] Positive values indicate deposition, negative values indicate erosion

APPENDIX B

Figures

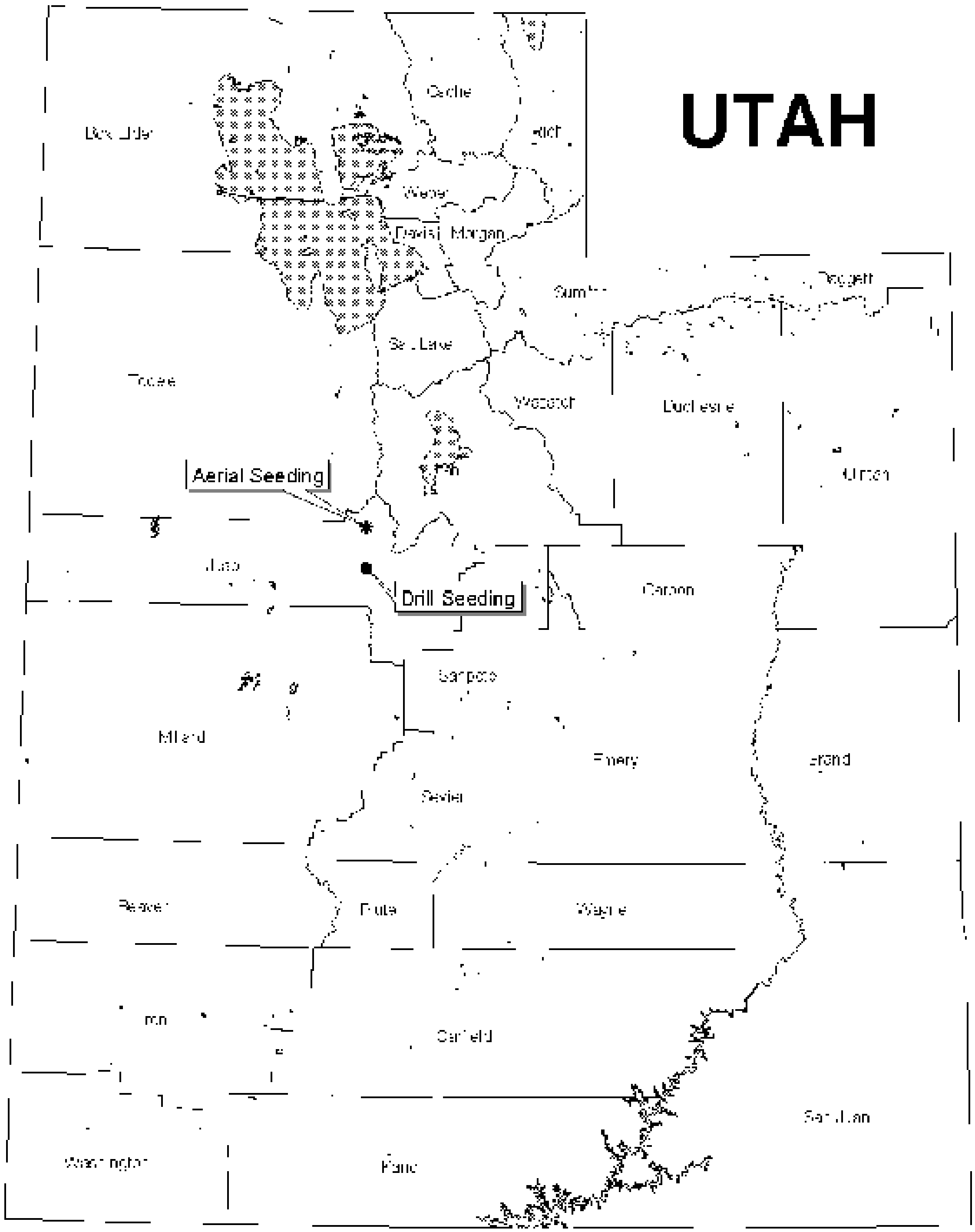

Figure 1. Location of fire rehabilitation seeding trials.

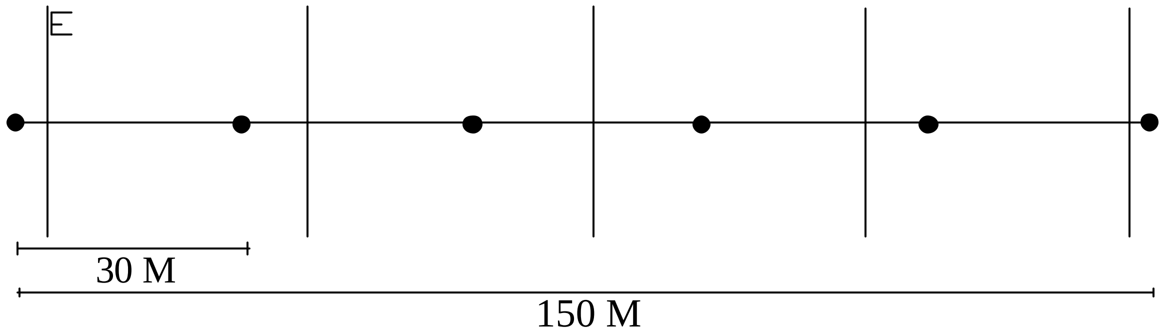

Figure 2. Sampling transect for vegetation response after fire rehabilitation in Utah. Twenty 0.25 m^2 quadrats were evenly placed and sampled on each stratified random 30 m cross belt.

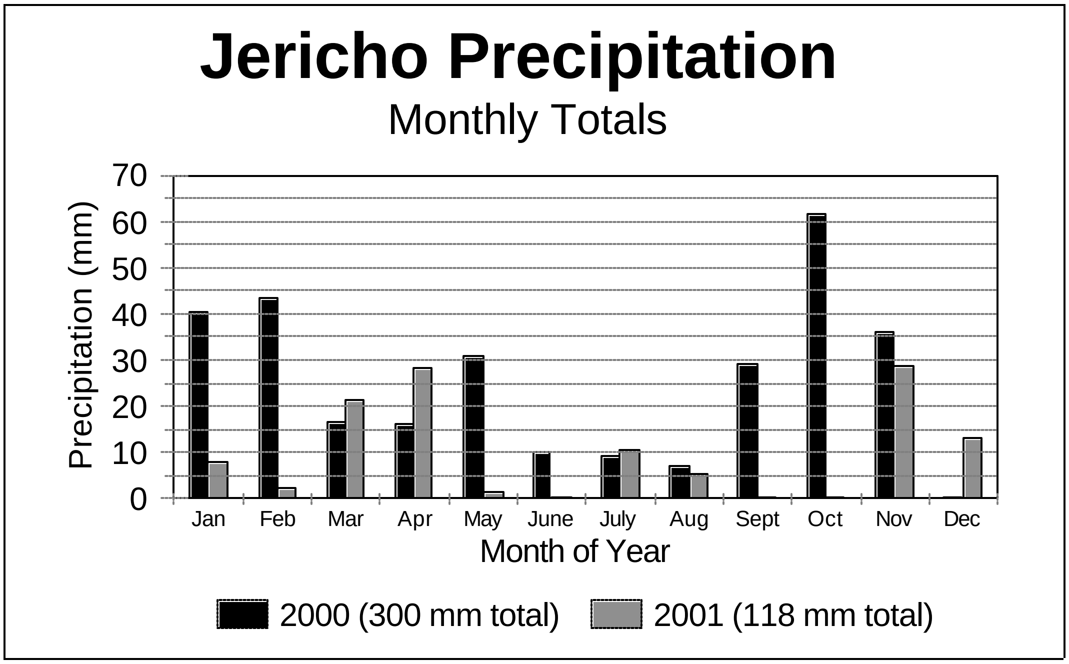

Figure 3. Precipitation data taken at Jericho, Utah, site of the drill seeding.

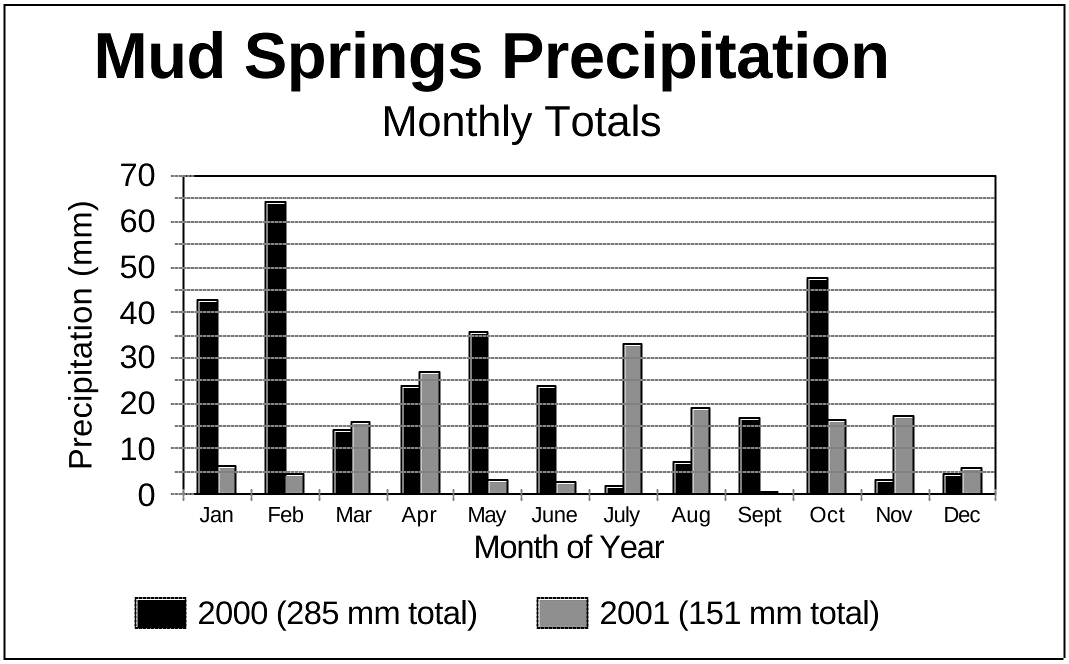

Figure 4. Precipitation data taken at Mud Springs Remote Automated Weather Station, Utah, near site of the aerial seeding/chaining. (WRCC 2002).